DEPARTMENT OF NATIONAL DEFENCE
CANADA

OPERATIONAL RESEARCH DIVISION

DIRECTORATE OF OPERATIONAL RESEARCH (JOINT & LAND)

DOR(J&L) RESEARCH NOTE 2000/03

A MODEL OF LOGISTIC MOVEMENTS DURING A HUMANITARIAN RELIEF OPERATION

BY

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&
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March 2000

OTTAWA, CANADA

National Defence Défense nationale

102-02190/

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OTTAWA, ONTARIO MARCH 2000

ABSTRACT

A simulation model originally developed in VENSIM is implemented as an Excel spreadsheet that can be used to analyze logistics movements during a potential humanitarian relief effort. The primary questions that can be addressed with this model involve balancing the strategic and tactical movements resources to maximize efficiency and the optimal introduction of additional movements resources to minimize the duration of the dangerous period. The Canadian Forces plans for OPERATION ABACUS, potential humanitarian relief in case of national infrastructure failures caused by the "Year 2000 bug", is used as an example.

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A MODEL OF LOGISTIC MOVEMENTS DURING A HUMANITARIAN RELIEF OPERATION

BACKGROUND

1. OPERATION ABACUS was in the planning stages for almost two years. This operation was intended to provide humanitarian relief in the event that the Year 2000 "Bug" created problems in the national infrastructure such as electricity, gas lines, telephone communication, etc. The seriousness of the Year 2000 "Bug" was compounded by the natural challenges of a normal Canadian winter. The Deputy Chief of Defence Staff established a team inside the Joint Staff to coordinate a Canadian Forces response at the strategic level. The Joint Staff Operational Research Team (JSORT) in the Operational Research Division was augmented to support the Joint Staff during this operation. The authors of this report were part of the J4 Logistics sub-team in the JSORT.

2. For many months, J4 Logistics was procuring equipment and supplies, and pre-positioning them across the country under the direction of J3 Operations. However, there was a great deal of uncertainty about what and where the Year 2000 "Bug" would strike. Therefore, the primary effort of J4 Logistics was to be the rapid reaction to arising problems anywhere in the country and the movement of relief to these localities. Therefore, it was felt that a model should be developed to assist with the rapid analysis of the movement requirements and the smooth transition from strategic transport to tactical distribution to meet localized requirements.

THE STRATEGIC ASSESSMENT

3. It was assumed that it would take a number of days to assess the requirement for relief if the Year 2000 "Bug" struck. The Joint Headquarters (JHQ) would conduct this assessment and recommend what logistics movements were required. In our model, we assumed that this requirement could be measured in Units of Demand (model variable names have their first letter capitalized). This could involve troops, generators, shelters,

supplies, etc. This requirement was determined outside the model by the JHQ and the Joint Staff and generated a Local Requirement that must be filled. Figure 1 shows the first step in the modelling effort. The Local Requirement can be viewed as a reservoir with a depth determined by the Demand that will be filled by distribution of relief by troops in the Task Force Area (Tactical Teams).

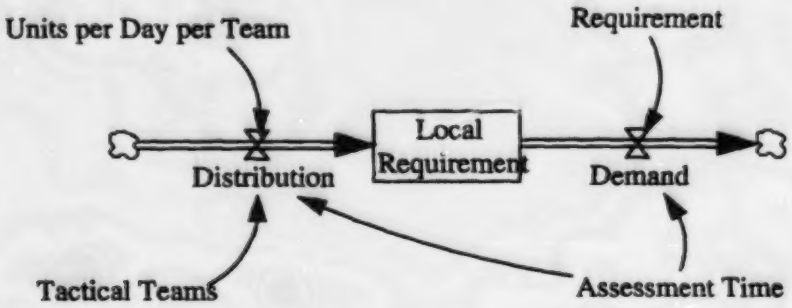

Figure 1: Establishing and Satisfying the Local Requirement

4. The Demand is assessed in the first days of the Operation and then the movements commence and continue until the Local Requirement is satisfied. The resulting time-line for the Operation would be as shown in Figure 2 with Requirement equal to 8,000 Units, the Assessment Time 1 day, the Deployment Time equal to 2 days, 85 Tactical Teams and the Units per Day per Team set to 10.

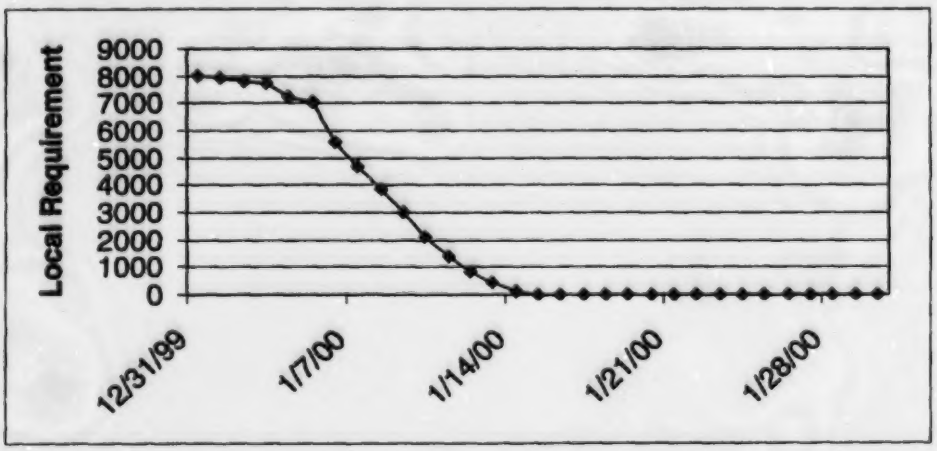

Figure 2: Timeline Profile of the Relief Requirement Remaining

TRANSPORT OF RELIEF INTO THEATRE

5. We have assumed in the previous model that there are sufficient Relief Supplies in Theatre to satisfy the Local Requirement. However, this may not be the case and there may be a requirement to move Relief from a Strategic Facility into Theatre. In this case, we have the model shown in Figure 3.

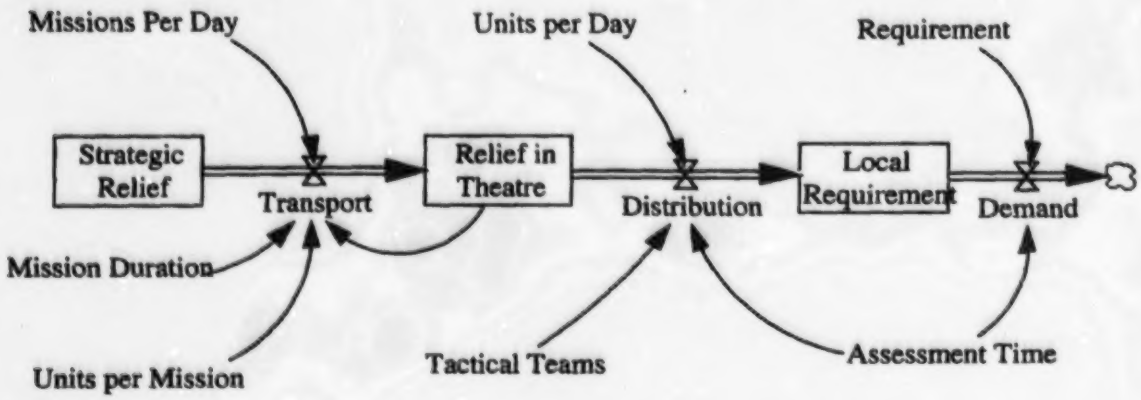

Figure 3: Movements from Strategic to Tactical Level

6. The resulting timeline shown in Figure 4 is based on the following additional data:

Strategic Relief = 25,000 Units
Initial Relief in Theatre = 1000 Units
Missions per Day = 1.75
Units per Mission = 1000
Mission Duration = 2 days

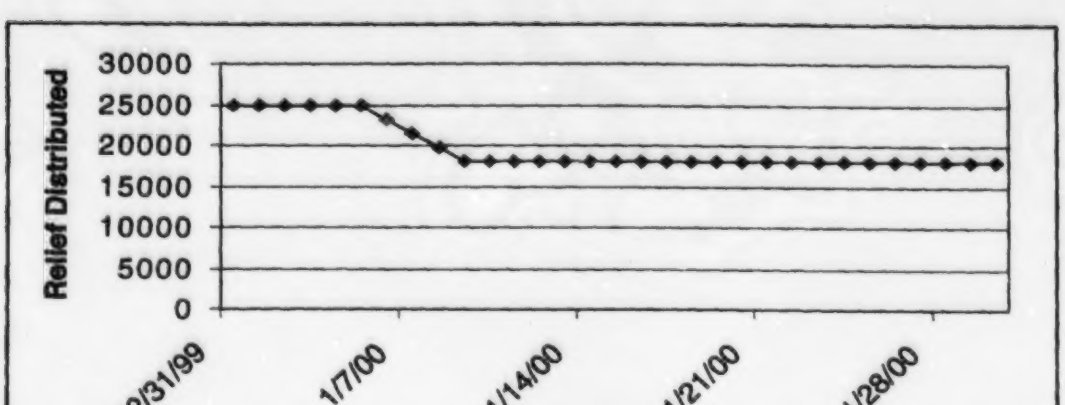

Figure 4: Timeline of Relief in Strategic Facilities

TACTICAL DISTRIBUTION RESOURCES IN THEATRE

7. We have assumed that there are sufficient Tactical Distribution Teams in Theatre in the previous model. This may not be the case. We will probably have to move Tactical Teams into Theatre using our Strategic Movements Resources. The following sub-model was developed to account for this contingency.

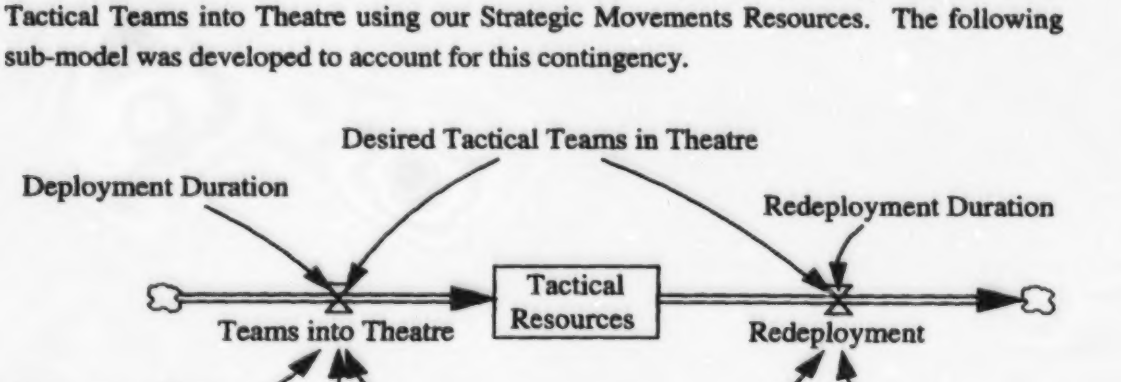

Figure 5: Model of Tactical Resources in Theatre

8. Figure 6 shows the results from this model when

Initial Tactical Teams in Theatre = 10

Desired Tactical Teams in Theatre = 85
Assessment Time = 1 day
Deployment Duration = 2 days
Operation Duration = 5 days
Redeployment Duration = 6 days
Mission Duration = 2 days
Missions per Day = 3.75 during Deployment and 1.42 during Redeployment, 0 otherwise

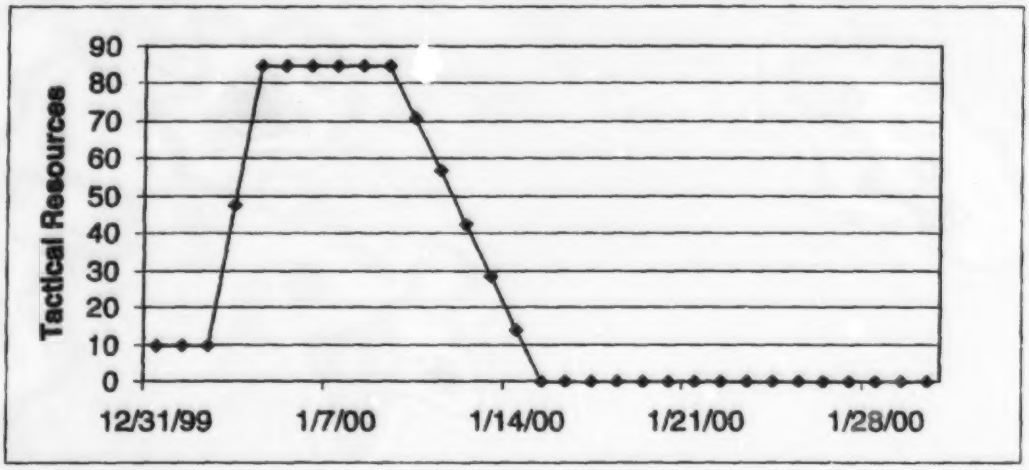

Figure 6: Timeline of Tactical Teams in Theatre

STRATEGIC MOVEMENTS RESOURCES

9. Again we have assumed in the previous model that the Strategic Movement Resources are unlimited which is obviously not the case. Therefore, we have developed the following model of Strategic Movements Resources.

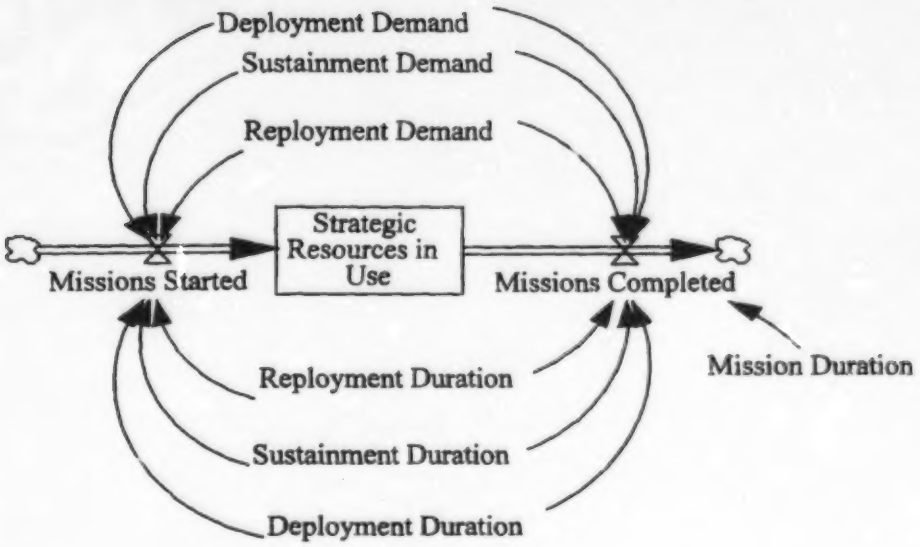

Figure 7: Model of Strategic Movement Resources

10. The following results are obtained for the Strategic Movements Missions per Day during the Operation when the parameters are

Mission Duration = 2 days
Deployment Demand = 3.75 missions/day
Deployment Duration = 2 day
Sustainment Demand = 1.75 missions/day
Sustainment Duration = 5 days
Redeployment Demand = 1.42 missions/day
Redeployment Duration = 6 days

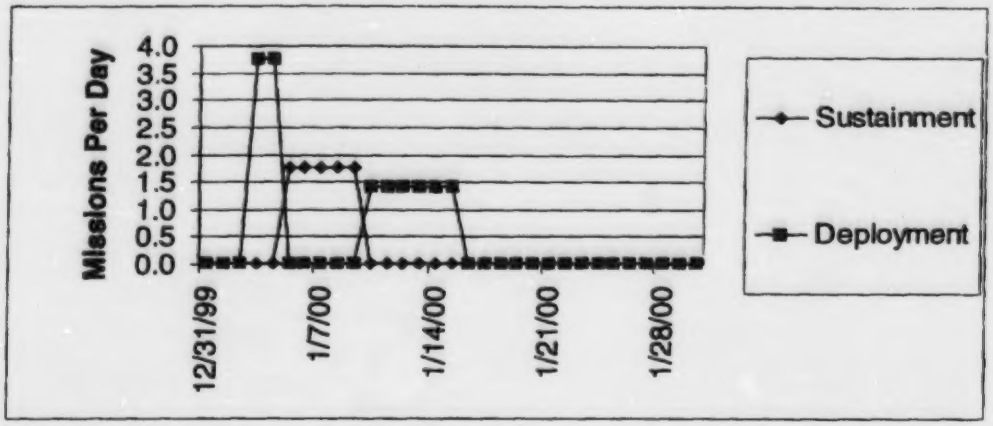

Figure 8: Strategic Movement Missions Started

PUTTING IT ALL TOGETHER

11. The final model is developed as a multiple sheet EXCEL Workbook (see Annex A for the formulae). The first worksheet contains the Parameters of the model. The second worksheet contains the Relief sub-model. The third worksheet contains the Distribution sub-model and the fourth spreadsheet contains the Transport sub-model.

12. One need only change the values on the Parameter worksheet and examine the results on the other spreadsheets. Balancing of the model is done through experimentation on the Relief Worksheet to determine the desired level of Tactical and Strategic Resources that are needed to complete the operation without any bottlenecks developing.

PARAMETERS		INITIAL VALUES	
Units per Day per Team	10	Local Requirement (units)	8000
Teams per Mission	10	Initial Relief in Theatre (units)	1000
Units per Mission	1000	Strategic Relief (units)	25000
Mission Duration (days)	2	Initial Tactical Teams in Theatre	10

TIMELINE	Date	Days	RESULTS	
Start Date	31-Dec-99		Deployment Missions per Day	3.75
Assessment Completed	1-Jan-00	1	Desired Tactical Teams	85
First Deployment Mission	3-Jan-00		Sustainment Lift (missions/day)	1.75
Deployment Completed	5-Jan-00	2	Redeployment Missions per Day	1.42
Employment Completed	10-Jan-00	5		
First Redeployment Mission	12-Jan-00			
Redeployment Completed	18-Jan-00	6		

Figure 9: The Parameters Worksheet

13. For example, if the Operation were to be completed in 15 days based on a requirement of 8,000 units of demand, by a trial and error process, we could easily find that 85 Tactical Teams should be deployed into Theatre to distribute the 8000 Units of Relief and 1.75 Missions per Day of Relief should be shipped during the Sustainment Phase to ensure the necessary Relief is in Theatre to be distributed.

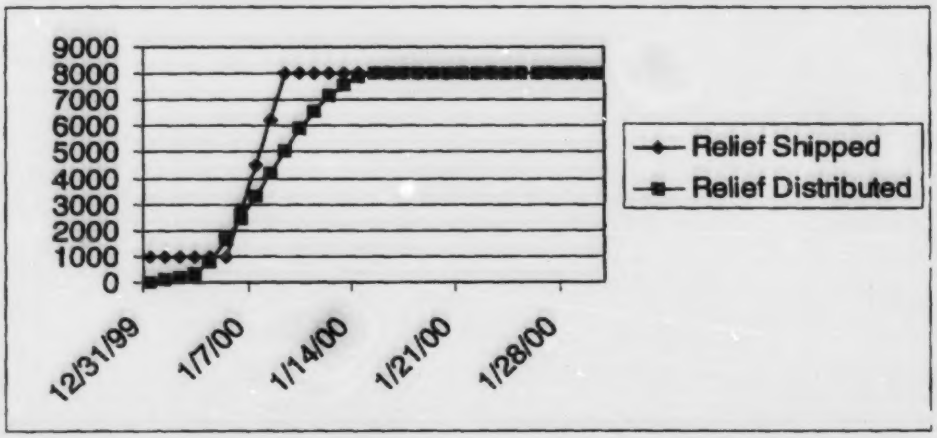

Figure 10: Balanced Resource Utilization

14. As we have seen in the previous graphs, although the Operation would be completed in 15 days, it would take 2 more days to complete the Redeployment of the Tactical Teams.

CONCLUDING REMARKS

15. We have built a simulation of the logistics movements during a relief operation. Fortunately, OPERATION ABACUS, in January 2000, did not require this type of relief. However, this model could be useful for other humanitarian relief operations in the future.

16. The model was designed using the interactive graphical capabilities of the System Dynamics software VENSIM (Ref. 1) and then adapted to EXCEL for distribution (Ref. 2). This was found to be an efficient modelling technique that has been used in the past successfully (see Ref. 3) and should be used in the future to develop models of other operational scenarios.

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1. Vensim Personal Learning Edition, User's Guide Version 3.0, Ventana Systems Inc, 1997.

2. Dodge, Mark; Chris Kinata and Craig Stinson; Running Microsoft Excel 97; Microsoft Press; Redmond Washington, 1997.

3. Taylor, Ivan and Major James Richardson, Production Lead-Time, Warning Time and Stockpile Costs, DOR (J&L) Research Note 9911, December 1999.

ANNEX A
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MARCH 2000

FORMULAE FOR THE HUMANITARIAN RELIEF MODEL

THE PARAMETERS WORKSHEET

1. The values in the Parameters Worksheet under the heading Parameters and Initial Values are input by the user.

2. The Timeline is computed based on the input of the Start Date in calendar time and the days to complete the Assessment, the Mission Duration, the days to complete the Deployment, the days to complete the Employment and the days to complete the Redeployment which are input by the user.

3. The Results section is computed as follows. The Desired Tactical Teams and the Sustainment Lift are imported from the Relief Worksheet (see below). The values for these results are found using a trial and error approach in the Relief Worksheet that ensures that the Operation is completed on time with no unnecessary expenditure. Then the Deployment Missions per Day is computed as:

(Desired Tactical Teams- Initial Tactical Teams in Theatre)/(Days to Complete the Deployment)

The Redeployment Missions per Day is computed as:

(Desired Tactical Teams)/(Days to Complete the Redeployment).

The number of Sustainment Missions per Day is computed as

(Sustainment Units Required Per Day) / (Units per Mission)

THE RELIEF WORKSHEET

4. Operation is assumed to run for 40 days. However, this can be easily extended in the Worksheet if necessary. As mentioned above, the Relief Worksheet can be used to fine-tune the Operational factors (Desired Tactical Teams in Theatre and Desired Sustainment Lift) to avoid any bottlenecks. The cells containing these parameters can be found below the Timeline calculations. One need only modify these parameters to ensure that the Relief Shipped and the Relief Distributed equals the Relief Requirement.

5. The Operation is divided into Phases that are coded in the right-most column of the Worksheet. The '0' Phase is Assessment. The '1' Phase is Out-Going Transit. The '2' Phase is Deployment. The '3' Phase is Employment/Sustainment. The '4' is In-Coming Transit. The '5' Phase is Redeployment and the '6' Phase is Completion. These Phases are computed using the Timeline in the Parameters Worksheet and later used in other calculations.

6. The Strategic Relief (Relief in Strategic Facilities) is recomputed every day during the Employment/Sustainment Phase. The calculation is

> (Strategic Relief on the Previous Day) – (Number of Sustainment Missions) * (Units per Mission).

The Number of Sustainment Missions is computed on the Transport Worksheet and the Units per Mission is input on the Parameter Worksheet.

7. The Cumulative Relief Shipped is computed as

> (Relief Shipped by Previous Day) – (Strategic Relief on Previous Day) + (Strategic Relief on Current Day)

8. The Cumulative Relief Distributed is computed as

> (Relief Distributed by Previous Day) + (Units Distributed per Day per Team) * (Tactical Teams in Theatre)

Units Distributed per Day per Team is an input in the Parameters Worksheet and Tactical Teams in Theatre is calculated on the Distribution Worksheet.

9. The Relief in Theatre is computed as

(Cumulative Relief Shipped) – (Cumulative Relief Distributed)

but is not allowed to become negative.

10. The Local Requirement Remaining is calculated as

(Initial Local Requirement) – MIN(Cumulative Relief Shipped, Cumulative Relief Distributed)

THE DISTRIBUTION WORKSHEET

11. In the Distribution Worksheet, the number of Tactical Teams in Theatre is calculated for each day of the Operation as follows:

If the Phase < 2 (i.e. prior to deployment), then

Tactical Teams in Theatre = Initial Tactical Teams in Theatre

If the Phase =2 (i.e. deployment), then

Tactical Teams in Theatre = Tactical Teams in Theatre the Previous Day + (Desired Tactical Teams in Theatre – Initial Tactical Teams in Theatre)/(Days of Deployment)

If the Phase = 4 or 5 (i.e. In-Coming Transit or Redeployment), then

Tactical Teams in Theatre = MAX(Tactical Teams in Theatre on Previous Day – (Desired Tactical Teams in Theatre/Days of Redeployment), 0)

Otherwise, Tactical Teams in Theatre does not change from the previous day.

THE TRANSPORT WORKSHEET

12. The Transport Worksheet computes the number of Strategic Missions started per day as follows. The number of Deployment or Redeployment Missions per day is:

> ABS(Tactical Teams in Theatre on the Previous Day – Tactical Teams in Theatre on Current Day) / (Teams Per Mission)

The Tactical Teams in Theatre is imported from the Distribution Worksheet and the Teams per Missions is an input from the Parameters Worksheet.

13. The Sustainment Missions per day is calculated in the Parameters Worksheet and imported to the Transport Worksheet if the Phase in the Relief Worksheet is '3' (i.e. employment).

14 The Deployment/Redeployment Missions are added with the Sustainment Missions to determine the number of Strategic Missions that are started per day throughout the Operation.

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1 ORIGINATOR (the name and address of the organization preparing the document Organizations for whom the document was prepared e g Establishment Sponsoring a contractor's report, or tasking agency, are entered in Section 8)

Operational Research Division
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2 SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable)

UNCLASSIFIED

3 TITLE (the complete document title as indicated on the title page Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title)

A Model of Logistic Movements during Operation ABACUS

4 AUTHORS (last name, first name, middle initial)

Taylor, Ivan W. and LCol Richiero, Frederic

5 DATE OF PUBLICATION (month Year of Publication of document)

March 2000

6a NO OF PAGES (total containing information Include Annexes, Appendices, etc) 20

6b NO OF REFS (total cited in document) 3

7 DESCRIPTIVE NOTES (the category of document, e g technical report, technical note or memorandum If appropriate, enter the type of report e g interim, progress, summary, annual or final Give the inclusive dates when a specific reporting period is covered)

Research Note

8 SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development Include the address)

J4 Movement

9a PROJECT OR GRANT NO (if appropriate, the applicable research and development project or grant number under which the document was written Please specify whether project or grant)

1970-3

9b CONTRACT NO (if appropriate, the applicable number under which the document was written)

10a ORIGINATOR's document number (the official document number by which the document is identified by the originating activity This number must be unique to this document)

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Humanitarian Relief
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